

Key Issues in Modulating Retroreflector Technology

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LONG-TERM GOAL

The long term goal of this effort is to develop an optical modulating retroreflector which can support data rates of a Mbps and higher. Inherent to this goal is the ability of the device to exploit the high bandwidth inherent in optical wavelengths, be covert, jam resistant, and alleviate the rf frequency allocation problem. The device would eliminate the need to fly a telescope for onboard acquisition and tracking characteristic of a one-way laser and therefore significantly reduces payload mass, size, and complexity. Figure 1 illustrates the concept.

OBJECTIVES

Optical communications using modulating retroreflectors requires a fast modulator technology to provide high data throughput. Over the last decade multiple quantum well (MQW) modulators have been used extensively in fiber optic communication systems to allow high bit rate communications. In this effort, we will address some of the technical challenges in adapting this technology to free space optical communications using retroreflectors. In particular, this application requires a large area modulator that can work in the wavelength range of 0.8-1.1 μm . This wavelength range is important because many good laser sources are available there. These include laser diodes, Ti:Sapphire lasers, and Nd:YAG lasers, all of which are candidates for transmitters in laser communication systems. The development of modulating retroreflector technology requires parallel development of modulator technology and optical retroreflector communications technology. The interplay of these two areas is important because the requirements of the optical retroreflector communications link feed directly into the optimal design of the multiple quantum well modulator. This effort examines some of the most important driving issues in both these technological areas.

APPROACH

The development of modulating retroreflector technology requires parallel development of modulator technology and optical retroreflector communications technology. The interplay of these two areas is important because the requirements of the optical retroreflector communications link feed directly into the optimal design of the multiple quantum well modulator. This proposal examines some of the most important driving issues in both these technological areas. There are several technical challenges

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associated with the development of these modulators. First, the desired wavelength range requires the use of InGaAs/AlGaAs quantum wells, rather than the more common GaAs/AlGaAs system. InGaAs/AlGaAs is a strained quantum well system. Providing thick quantum well structures with good electrical and optical qualities will require the growth of several test structures with different designs. In this effort, we initiated the fabrication of MQW devices of different architectures. We will then experimentally examine the effects of buffer design, well thickness, and electrode thickness on device performance. An additional issue is speed. RC charging times for rates of to about 100 MHz limits the speed of MQW modulators. In fiber optic communication systems, the modulator area can be kept quite small to reduce the device capacitance. For modulating retroreflector communication, in the most conventional architecture, the MQW modulator must have the same aperture as the retroreflector ($\sim 1 \text{ cm}^2$), significantly increasing its capacitance. We are addressing this issue in two ways. First we are seeking to reduce the series resistance in the modulator using highly doped, thick semiconductor contact layers as well as metallic transparent electrodes. We will also address the speed issue by examining alternative retroreflector architectures that will allow the quantum well aperture to be smaller than the retroreflector aperture, thereby reducing device capacitance. Specifically, we are examining a form of pixellation to that end. These two approaches are being compared in terms of speed and optical throughput and characterized experimentally. Six new wafer growths of different architectures were made in this past year to determine optimum parameter sets over the FY98 period of performance. Basic issues in the communications link are also being considered. Video rate transmission was considered and demonstrated over several meters which required consideration of fundamental communications requirements between the signal recorded (video), transmitted via the Modulating Retroreflector, and received. A bench-level capability to characterize device performance in terms of Bit Error Rate as a function of photon flux and drive current was also built up during this period.

WORK COMPLETED

During this period of performance, we demonstrated a free space optical link, which transmitted video over a 17 meter link using a Multiple Quantum Well modulator combined with an optical retroreflector. We believe these are the first results reported demonstrating a high speed free space optical data link using multiple quantum well shutters combined with retroreflectors for viable free space optical communications.

RESULTS

Video images were transmitted over an 859 nanometer link at a rate of 460 kilo bits per second, where rate of modulation was limited by demonstration hardware, not the modulator. Reflection architectures for the modulator were used although transmission architectures were also been investigated. The modulator was a GaAs/Al_{0.3}Ga_{0.7}As quantum well which was designed and fabricated for use as a shutter at the Naval Research Laboratory. The data rate of 460 kbps was supported by the reflective MQW modulator with a maximum power draw of 50 mW. The pulse train recovered in the NRL MQW retroreflector system is shown in Figure 3. From this figure, it can be seen that the digitized data stream from the video image was converted and transmitted with integrity on the carrier beam. In order to ease reconfigurability, computer interfaces were used at the transmit and receive ends, introducing substantial overhead to the frame recovery rates. The MQW device itself was able to support 620

KBPS rates in separate pulse train measurements. Frame rates on the order of 3 fps were achieved. Device fabrication and packaging of the modulator itself was improved and is shown in Figure 4.

IMPACT/APPLICATION

As previously stated, success in this endeavor can provide a device for free-space optical data transfer which exploits the high bandwidth inherent in optical wavelengths, is covert, jam resistant, and alleviates the rf frequency allocation problem. It eliminates the need to fly a telescope for onboard acquisition and tracking characteristic of a one-way laser and therefore significantly reduces payload mass, size, and complexity. Its development is consistent with Science and Technology Guidance (STRG). Specifically, such a device enhances link technology supporting Low Probability of Intercept, Anti Jam, and High Bandwidth (STRG97 1A; Tier H). Due to its small divergence and required directivity of interrogation beam, the device supports covert communications and depending on the transmitter/receiver characteristics, can support ground-to-air, air-to-air, and space-to-space platforms (STRG 97 1B; Tier: H). Finally, because optical wavelengths are used, the antenna, or telescope, is quite small (STRG97 1G; Tier: M).

TRANSITIONS

This effort transitions a ONR/NRL 6-1 program on quantum well technology into a 6.2 effort to create a device using the technology. The Modulation Retro and/or retroarray is envisioned to transition to a 6.3A level demonstration but requires the three year 6-2 program support to develop an understanding of the device and its interplay with key parameters in a candidate link.

RELATED PROJECTS

None at this time.

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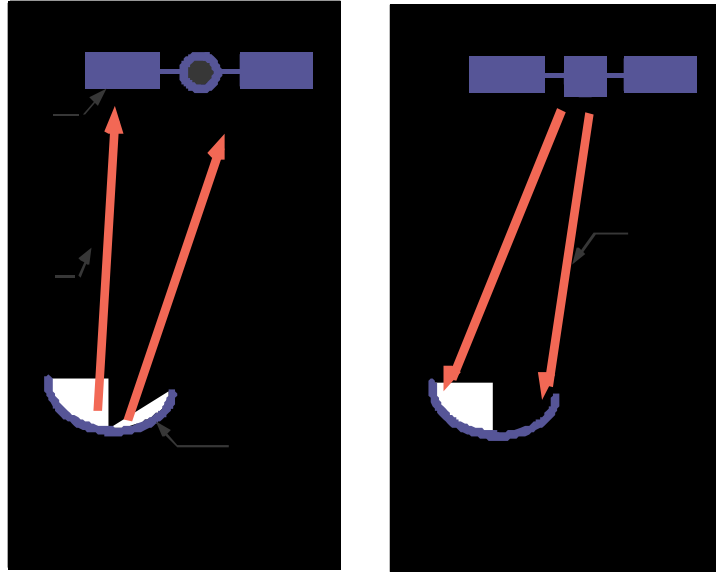


Figure 1. Concept of Operations for Ground-to-Space Optical Communications using a Modulating Retroreflector Array: (1) Satellite; (2) Transmitter/Receiver; (3) Interrogation Beam; (4) Modulated Beam.

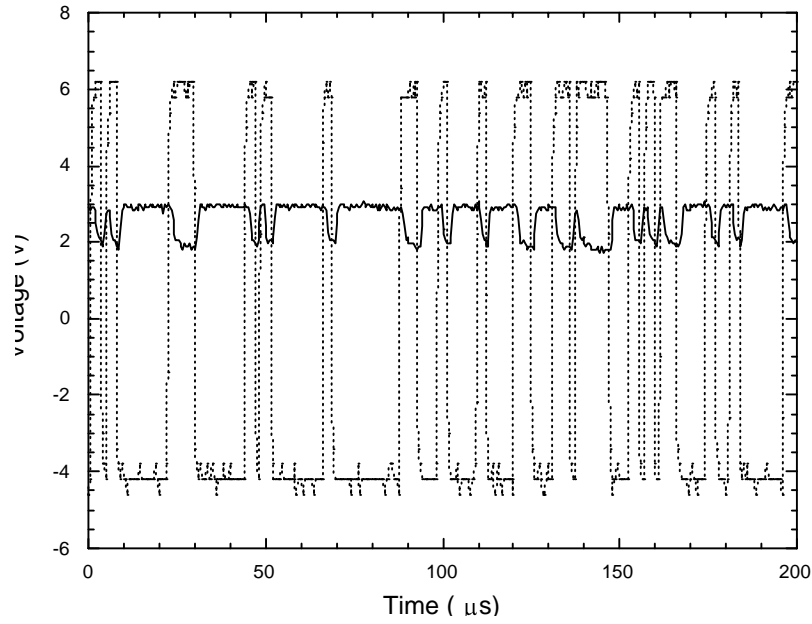


Figure 2. Driver Voltage and APD Output of Received Signal. The dashed line is the driver voltage to the MQW. The solid line represents the avalanche photodiode output before amplification and signal configuration.

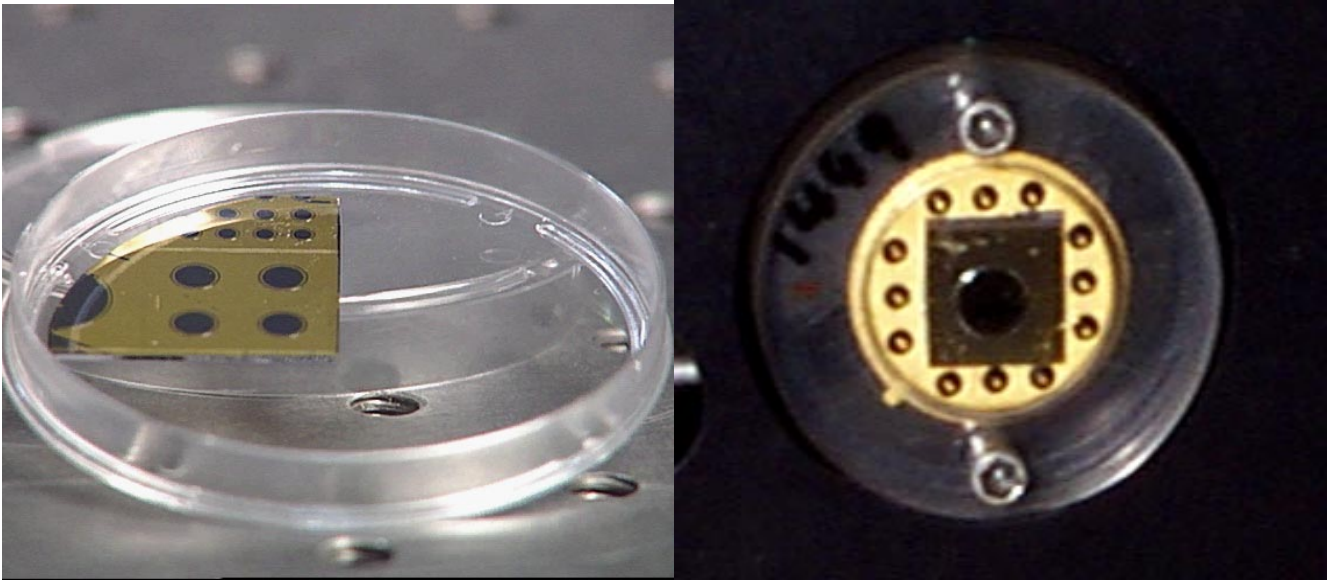


Figure 3. Fabrication and Packaging of MQW modulator wavers: Unpackaged on left; Packaged for coupling to retroreflector on right.